25. (New) The fuel injector of claim 22, wherein the coating extends into the at least one discharge orifice.--.

Remarks

This Preliminary Amendment cancels without prejudice original claims 1 to 15 and new/substitute claims 1 to 9 in the underlying PCT Application No. PCT/DE00/02043, and adds without prejudice new claims 16 to 25. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. In the Marked Up Version, underlining indicates added text and bracketing indicated deleted text. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE00/02043 includes an International Search Report, dated November 13, 2000. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

The underlying PCT application also includes an International Preliminary Examination Report, dated September 24, 2001, and an annex (including new/substitute claims 1 to 9). An English translation of the International Preliminary Examination Report and the annex accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,
KENYON & KENYON

Dated: 1/2/2002

By: Richard L. Mayer (By Reg. No. 33,865 Aaron C. Deditch)
Richard L. Mayer
(Reg. No. 22,490)

One Broadway
New York, NY 10004
(212) 425-7200

CUSTOMER NO. 26646

435000

FUEL INJECTOR

[Background Information
]
FIELD OF THE INVENTION

The present invention [is based on]relates to a fuel injector[according to the species defined in the main claim].

BACKGROUND INFORMATION

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, particularly with direct injection of gasoline or [the]injection of diesel fuel, [the]a problem [generally occurs]may occur; namely, that the downstream tip of the injectors projecting into the combustion chambers [is]may get coked by fuel deposits[,] (that is[to say], soot particles formed in the flame front may deposit on the valve tip). [That is why, for previously known]Thus, with injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters ([e.g.]such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) may exist[s] over the[ir] service life of the injectors, which [can]may lead to disturbances in the running of the internal combustion engine[, up to the point of] and a failure of the injectors.

[Summary of the Invention

The]SUMMARY OF THE INVENTION

An exemplary fuel injector [of]according to the present invention [having the characterizing features of the Main Claim has]may have the advantage that [these aforesaid]the negative effects of the coking (soot deposit) on the valve tip projecting into the combustion chamber [are]may be reduced or

2L244510201

eliminated. The application[, according to the present invention,] of coatings on the downstream valve end, [above all,]especially around the outlet areas of the discharge orifices, may reduce[s] or [prevents the]prevent coking or formation of covering (soot) on the valve end [generally]that may negatively [influencing]influence the spray parameters and the valve function.

[Advantageous further developments and improvements of the fuel injector indicated in the Main Claim are rendered possible by the measures specified in the dependent claims.
]
It [is]may be advantageous to apply layers on the valve end, by which either a catalytic conversion (burning) of the deposits [is]may be effected[,] or the surface energy and/or the surface roughness of the component to be coated [is]may be reduced, a change in the wetting properties thereby being achieved, or the formation of a reaction layer thereby being prevented.

[Brief Description of the Drawing

An exemplary embodiment of]BRIEF DESCRIPTION OF THE DRAWINGS
Figure 1 shows an exemplary fuel injector according to the present invention[is shown in simplified fashion in the Drawing, and is explained in detail in the following description. Figure 1 shows a fuel injector] inserted into a location bore of a cylinder head[;].

Figure 2 shows a longitudinal cross-section of an exemplary fuel injector [in]a[longitudinal section;]ccording to the present invention.

Figure 3 shows[a first exemplary embodiment of] a valve end coated according to [the invention; Figure 4 shows a second]an exemplary embodiment of [a]the present invention.

Figure 4 shows another valve end coated according to an exemplary embodiment of the present invention[;].

Figure 5 shows an alternative guide and seat area on [the]a valve end at the spray-discharge side[;].

Figure 6 shows a longitudinal cross section of [a]an exemplary fuel injector according to the present invention for an auto-ignition internal combustion [engines; and]engine.

Figure 7 shows [the]an end of the fuel injector [according to]of Figure 6 on the combustion chamber side.

[Description of the Exemplary Embodiments
]DETAILED DESCRIPTION

Figure 1 shows a cut-off segment of a cylinder head 1 of an internal combustion engine, particularly a mixture-compressing internal combustion engine with externally supplied ignition[, in a cut-off segment]. Formed in cylinder head 1 is a graded location bore 2 [which]that extends symmetrically along a longitudinal axis 4 up to a combustion chamber 3. A fuel injector 5, according to an exemplary embodiment of the present invention, is inserted into location bore 2 of cylinder head 1. Fuel injector 5 [is]may be used for[the] direct injection of fuel, particularly gasoline, but may also, for example, be used for injection of diesel, as [is]shown [with reference to]in Figures 6 and 7, into combustion chamber 3 of the internal combustion engine. Fuel injector 5 [is preferably able to]may be actuated electromagnetically via an electrical connecting cable 6. The fuel [is]may be supplied to fuel injector 5 [via]by an intake nipple 7. [F]The fuel injector 5 [shown in]of Figure 1 is a[so-called] top-feed injector, in which the fuel is guided in the axial direction from intake nipple 7 through entire injector 5, [it]the fuel being ejected at end 8 on the spray-discharge side, opposite the end on the intake side, into combustion chamber 3.

To protect fuel injector 5 near [to]combustion chamber 3 from overheating, injector 5 [is]may be at least partially surrounded, for example, with a thermal-protection sleeve 9 [likewise]also inserted in location bore 2, [it also being possible to dispense with]although the thermal-protection sleeve may be dispensed with.

Figure 2 shows a cross-section of an exemplary[embodiment of a] fuel injector 5 according to the present invention[in a sectional view]. [It is a]An electromagnetically operable valve[that], which has a tubular, largely hollow-cylindrical core 11 [which]that is at least partially surrounded by a magnetic coil 10[and], is used as the internal pole of a magnetic circuit. [A, f]For example, a graded plastic coil form 13 receives a winding of magnetic coil 10 and, in conjunction with core 11 and a non-magnetic intermediate part 14 partially surrounded by magnetic coil 10, permits a particularly compact and short [design of the]injector in the area of magnetic coil 10. Instead of the electromagnetic actuating element, fuel injector 5 may also be actuated in a piezoelectric or magnetostrictive manner.

Provided in core 11 is a traversing longitudinal opening 15, which extends along a longitudinal valve axis that coincides with the longitudinal axis 4 of the location bore 2 of Figure 1. Core 11 of the magnetic circuit also serves as intake nipple 7. Fixedly joined to core 11 above magnetic coil 10 is an outer metallic ([e.g.]such as, for example, ferritic) housing part 16 which, as an external pole or an outer conductive element, closes the magnetic circuit and completely surrounds magnetic coil 10, at least in the circumferential direction. Provided in the longitudinal opening 15 of core 11 on the intake side is a fuel filter 17 [which]that filters out[those] fuel components [which]that, because of their size, [could]may cause clogging or damage [in]to the injector.

Joined imperviously and fixedly to upper housing part 16 is a lower tubular housing part 18 which, for example, <u>may</u> enclose[s] or receive[s] an axially movable valve part [made of]<u>including</u> an armature 19,[as well as] a bar-shaped valve needle 20 and an elongated valve-seat support 21[, respectively]. Both housing parts 16 and 18 [are]<u>may be</u> permanently joined to one another by, for example, a circumferential welded seam. The sealing between housing part 18 and valve-seat support 21 [is]<u>may be</u> effected, for example, by a sealing ring 22. Valve-seat support 21 [has]<u>includes</u>, over its entire axial extension, an inner through hole 24 [which]<u>that</u> runs concentrically with respect to the longitudinal valve axis.

With its lower end, which [at the same time]also [represents]<u>functions as</u> the downstream termination of entire fuel injector 5, valve-seat support 21 surrounds a disk-shaped valve-seat element 26, fitted into through hole 24, [having]<u>including</u> a valve-seat surface 27 tapering frustoconically downstream. Arranged in through hole 24 is valve needle 20<u>,</u> which has a valve-closure section 28 at its downstream end. This, for example, spherical, partially ball-shaped and conically tapering valve-closure section 28 cooperates[in known manner] with valve-seat surface 27 provided in valve-seat element 26. Downstream of valve-seat surface 27, at least one discharge orifice 32 for the fuel is introduced in valve-seat element 26.

[On the one hand, a]<u>A</u> guide opening 34 provided in valve-seat support 21 at the end facing armature 19[,] and[on the other hand,] a disk-shaped guide element 35 arranged upstream of valve-seat element 26 and [having]<u>including</u> a dimensionally accurate guide opening 36[,] are used for guiding valve needle 20 during its axial movement with armature 19 along the longitudinal valve axis.

The lift of valve needle 20 [is]may be predefined by the installed position of valve-seat element 26. One end position of valve needle 20, when magnetic coil 10 is not energized, [is]may be established by the contact of valve-closure section 28 on valve-seat surface 27 of valve-seat element 26[, while the other]. Another end position of valve needle 20, when magnetic coil 10 is energized, [is yielded]may be established by the contact of armature 19 on the downstream end face of core 11. The surfaces of the components in the [last-named]stop region [are]may be, for example, chromium-plated.

The electrical contacting of magnetic coil 10, and thus its excitation, [is]may be effected [via]by contact elements 43 ,which, outside of coil form 13, [are]may be provided with a plastic extrusion coat 44. Plastic extrusion coat 44 may also extend over further components ([e.g.]such as, for example, housing parts 16 and 18) of fuel injector 5. Leading out of plastic extrusion coat 44 is electrical connecting cable 6, [via]by which magnetic coil 1[is]0 may be energized.

The guide and seat area provided in the end of valve-seat support 21 on the spray-discharge side[,] is formed in its through hole 24 by three axially sequential, disk-shaped, functionally-separate elements. Guide element 35, a swirl element 47 and valve-seat element 26 follow one another in the downstream direction. A compression spring 50 enclosing valve needle 20 secures [the three]guide element[s] 35, swirl element 47 and valve-seat element 26 in place in valve-seat support 21. Swirl element 47 may be produced inexpensively, for example, by stamping, wire EDM (electrical discharge machining), laser cutting, etching or other [known]methods from[a] sheet metal, or by electrodeposition. An inner swirl chamber and a plurality of swirl ducts opening[through] into the swirl chamber are provided in swirl element 47. In this way, before valve seat 27, a swirl component [is]may be impressed on the fuel to be ejected, so that the flow may

MARKED UP VERSION OF SUBSTITUTE SPECIFICATION

enter[s] with a swirl into discharge orifice 32, and a fine-swirled and well-atomized spray [is]may be delivered into combustion chamber 3.

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, the problem [generally]may occur[s] that the downstream tip of the injector projecting into the combustion chamber [is]may get coked by fuel deposits[,] (that is to say, soot particles [formed]in the flame front may deposit on the valve tip). [That is why]Thus, for[previously known] injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters ([e.g.]such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) exists over the[ir] service life of the injectors, which [can]may lead to disturbances in the running of the internal combustion engine, up to [the point of]a failure of the injectors.

According to an exemplary embodiment of the present invention, it is believed that these aforesaid problems [are]may be reduced or eliminated by applying coatings at valve end 8. In this context, different effects on surface 54 of the component to be coated, [e.g.]such as, for example, on valve-seat element 26 made of Cr-steel, [are]may be attained by different coatings[; u]. Ultimately, however, [all]these measures are [aimed at reducing]intended to reduce or [preventing]prevent the coking or formation of covering (soot) on valve end 8, which may ha[s]ve a[generally] negative influence on the spray parameters and the valve function. Individual coating possibilities are further described[in greater detail] in the following.

Catalytically acting layers [represent]may form a first group of coatings. The electrolytically applied layers may provide for a catalytic conversion (burning) of the deposited soot

particles or prevent the deposit of carbon particles[from the start]. Suitable materials for such a coating to avoid coking [are]may be cobalt[and], nickel oxides and oxides of alloys of these metals[indicated]. The noble metals Ru, Rh, Pd, Os, Ir and Pt, and alloys of these metals, among themselves or with other metals, may also exhibit catalytic effectiveness. The desired layers [are]may be produced, for example, by electrochemical or external-currentless metal deposition. In the case of Ni, Co or their alloys, oxide formation in air or an additional oxidation step (using a wet chemical treatment, plasma) may also be used.

[The c]Coatings with which[the] wetting properties on corresponding surface 54 [are]may be changed, form a second large group of coatings. [Achieved by the]These coatings [in this case is that]may reduced the surface energy and/or the surface roughness of [the]critical regions at valve end 8[is/are reduced]. The interfacial energy between surface 54 and the fuel [is]may thereby be increased, which [means]causes the wetting to deteriorate[s]. In this way, the fuel drops at the regions coated according to an exemplary embodiment of the present invention [are]may be able to drip off and [are]may be entrained by the surrounding flow at valve end 8. Permanent wetting of valve end 8 may no longer take[s] place. [Presenting themselves as s]Such layers [are]may be ceramic coatings, carbon coatings, which may be metal-containing or metal-free, or fluorine-containing coatings. The fluorine-containing coatings [are]may be, for example, heat-resistant PTFE-similar coatings or, in particular, organic ceramic coatings or so-called Ormocer® coatings made of fluorosilicate (FAS). For example, such fluorine-containing coatings [are]may be applied by spraying or dipping. Sapphire coatings [are]may also [conceivable]be applied.

A third group [is formed by the]of coatings may be formed, with which a reaction layer [can]may be prevented. [Among

these are]Coatings for this third group may be, for example, nitrite layers (TiN, CrN) or oxide layers (tantalum oxide, titanium oxide). Similar to sputtering, for these layers, particles vaporized in a vacuum furnace [are]may be deposited on surfaces 54 to be coated.

[
]The regions to be coated at valve end 8 are, in particular, those [which]that immediately surround the at least one discharge orifice 32 in its outlet area 55[. Namely], since, a deposit of soot particles in discharge orifice 32 and/or at its immediate boundary edge may lead[s], in particular, to the disadvantageous influencing of the spray parameters ([e.g.]such as, for example, static flow quantity, spray dispersal angle, drop size, skeining ability) indicated above). Thus[, in any case], a coating should be applied at the downstream end (outlet area 55) of each individual discharge orifice 32, regardless of on which component of fuel injector 5 discharge orifice[s] 32 [are]may be formed.

Figures 3 and 4 show bottom views of two exemplary embodiments of valve ends 8[,] coated according to an exemplary embodiment of the present invention[, i]. In [bottom views which differ in that, in one case]Figure 3, entire downstream component surface 54 of the component [having]including discharge orifice 32, [here]shown in Figure 3 as valve-seat element 26, is coated[(]. In Figure [3), and in the other case]4, only an annular partial area of downstream component surface 54 is coated around the at least one discharge orifice 32[(Figure 4).
]. The dotted areas[are intended to clearly] show the coated regions. In Figures 3 and 4, outlet areas 55 of discharge orifices 32 lie in the drawing plane[. It should be emphasized that t] (not shown). The coatings may also extend slightly into discharge orifice 32.

In the exemplary embodiments [shown]of Figures 3 and 4,[in each case valve- seat] valve-seat element 26 is the component of fuel injector 5 [which]that forms downstream end 8 and has discharge orifice 32, so that the coating is[to be] applied at downstream end face 54 of valve-seat element 26. However, the application of a coating [according to the present invention]is not limited to a valve-seat element, but rather other valve components [which]that form downstream valve end 5 and thus project into combustion chamber 3 may also [have]include such a coating. For such components arranged downstream of valve seat 27 (see spray-discharge member 67 in Figure 5), as well, at least the regions immediately at discharge orifices 32 should be coated, so that the actual spray-discharge area [is]may be protected from coking.

Figure 5 shows an alternative guide and seat region at valve end 8 on the spray-discharge side, [in order]to [elucidate]show that [the assertions with respect to the]an exemplary coating [of]according to the present invention [are]may also be applicable to valve designs [which]that differ structurally. In th[is]e exemplary embodiment of Figure 5, a further disk-shaped spray-discharge member 67 is arranged downstream of valve-seat element 26. In this case, spray-discharge member 67 [has]includes discharge orifice 32. Discharge orifice 32 is inclined at an angle with respect to the longitudinal valve axis[,] and terminates downstream in a convexly curved spray-discharge region 66. Spray-discharge member 67 and valve-seat element 26 [are]may be permanently joined to one another by, for example, a welded seam 68 obtained by laser welding, the welding being carried out in an annular circumferential depression 69. In addition, spray-discharge member 67 [is]may be permanently joined to valve-seat support 21 by a welded seam 61. For example, the coating [is]may be applied[either] over entire curved spray-discharge region 66[,] or directly in a ring shape about outlet area 55 of discharge orifice 32, so that, relative to

the longitudinal valve axis, an off-center coating may exist[s] on[a] curved surface 54.

Figure 6 shows a longitudinal cross section through a fuel injector for auto-ignition internal combustion engines, particularly diesel engines, only the part facing the combustion chamber being shown. An enlargement of the end of fuel injector 5 on the combustion chamber side shown in Figure 6 is shown in Figure 7. [A component constructed as v]Valve member 72 is braced against a valve-retaining member 73 by a tension nut 75. Formed in valve member 72 is a bore 84, in which piston-shaped valve needle 20 is arranged[that], which is axially movable against a closing force. Bore 84 is implemented as a blind-end bore, the closed end of the bore 84 facing combustion chamber 3, forming a valve-seat surface 27 [which essentially]that has a truncated cone shape. Due to a bulge of the end of valve-seat surface 27 on the combustion chamber side, a blind hole 92 is formed, in whose wall at least one discharge orifice 90 is configured [connecting]that connects blind hole 92 to combustion chamber 3.

Valve needle 20 is divided into [a]two sections. The first section, which has a larger diameter than the second section, [facing]faces away from combustion chamber 3[, which has a larger diameter] and is guided in bore 84[, and a]. The second section [having]has a smaller diameter[, between which] than the first section, a pressure space 86 being formed between the second section and the wall of bore 84, [a]so that pressure space 86 [is formed which is able to]may be filled with fuel under high pressure [via]by an inlet passage 80 formed in valve-retaining member 73 and valve member 72. Due to the grading of the outside diameter of valve needle 20, a pressure shoulder 82 [is]may be formed[on it], which [is]may be arranged within pressure space 86. The fuel pressure in pressure space 86 produces a force on pressure shoulder 82 whose component operating in the axial direction is directed

contrary to the closing force operating on valve needle 20, and thus, given suitable fuel pressure, valve needle 20 [is]may be able to move against the closing force.

Formed on valve needle 20 at the end on the combustion chamber side is a valve-sealing surface 88, forming valve-closure section 28 (not shown in Figure 6 or Figure 7), which cooperates with [valve- seat]valve-seat surface 27 [in such a way]so that the at least one discharge orifice 90 is sealed against pressure space 86 by the contact of valve-sealing surface 88 on valve-seat surface 27. Due to the opening lift movement directed inwardly away from combustion chamber 3, valve-sealing surface 88 lifts off of valve-seat surface 27 and connects pressure space 86 to discharge orifice 90.

The catalytically active coating [is]may be applied, for example, over the entire end face of valve member 72 facing combustion chamber 3. [It is also possible to provide]Further, only curved outer surface 96 of blind hole wall 93 may be provided, which borders blind hole 92 and in which the at least one discharge orifice 90 is formed, with a coating. Provision may also be made to continue the coating into discharge orifice 90.

[Abstract]

ABSTRACT OF THE DISCLOSURE

[The present invention relates to a]A fuel injector[(5)], particularly a fuel injector projecting directly into a combustion chamber of an internal combustion engine, [having]including one fuel inlet[(7)],[having] an energizable actuating element[(10],[11, 19)] by which a valve-closure member [(28)]is able to be moved, [having]one fixed valve seat[(27)], with which the valve-closure member[(28)] cooperates for opening and closing the valve, and [having]one fuel outlet formed in a downstream valve end[(8)], the fuel outlet being formed by at least one discharge orifice [(32)]arranged downstream of the valve seat[(27)]. The valve-seat element [(26) having]includes at least one discharge orifice [(32)]has on its downstream end face[(54)], at least in an outlet area[(55)] of the discharge orifice[(32)], a coating [which]to prevent[s] coking in this region.

436279